# Regeneration of Woodland Vegetation after Deer Browsing in Sharon Woods Metro Park, Franklin County, Ohio[1]

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**Abstract.** **Overbrowsing by deer can decrease plant abundance and change plant species composition, especially in isolated forest fragments. Sharon Woods Metro Park, Franklin County, OH is a 308 ha suburban woodland preserve that had a deer population of 347 individuals in 1992 (112 deer/km$^2$), which was subsequently reduced to the currently maintained level of ~40 individuals (14 deer/km$^2$). Deer exclosures (~0.4 ha) established in 1990 in three habitats were used to compare vegetation that recovered under complete protection with that which had sustained continued browsing. Tree seedlings, herbaceous and shrub species richness, diversity, and floristic quality were quantified in browsed and fenced treatments as indicators of plant diversity. Percent ground cover was assayed as a measure of plant biomass. Total percent ground cover was significantly lower in browsed treatments in two of the three habitats. Species richness and floristic quality of forest floor species were consistently, though not significantly, lowered in browsed treatments where the more disturbance-tolerant native species increased in frequency and abundance. Reduced deer browsing has allowed some plant species to regenerate but not others. For example, pawpaw (*Asimina triloba*), American beech (*Fagus grandifolia*), and jewelweed (*Impatiens capensis*) are disturbance tolerant and/or unpalatable species that may inhibit regeneration of more sensitive species under browsing pressure. A further reduction in deer density to ~4 deer/km$^2$ and continued vegetation monitoring are recommended next steps for vegetation management at Sharon Woods.**

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## INTRODUCTION

The white-tailed deer (*Odocoileus virginianus*) is now acting as a keystone herbivore in the eastern United States. Pre-European settlement white-tailed deer densities were estimated to be ~4 deer/km$^2$ (Alverson and others 1988; Rooney and Dress 1997). Most of this region now contains areas where densities substantially exceed this value (Anderson 1994). Deer populations often reach particularly high densities in parks and preserves, with significant consequences for the plant communities within them (Augustine and Jordan 1998). In Northern Wisconsin's Flambeau River State Forest, for example, Anderson and Katz (1993) estimated the deer density at 50-100 deer/km$^2$, and in northeast Ohio's Cuyahoga Valley National Park, the population has been estimated at 17-35 deer/km$^2$ (Dengg 2002). Since deer are selective feeders, damage to plant species occurs differentially and herbivory is often not noticed until many species are impacted, sometimes resulting in a distinct browse line (Augustine and Frelich 1998; Webster and others 2001).

The impacts of deer browsing in several areas of the eastern US have been well studied. In northwestern Pennsylvania, Tilghman (1989) conducted a five-year study of the impact of browsing on tree seedlings, woody shrubs, and herbs in Allegheny Forest, and Rooney and Dress (1997) examined plant species loss after sixty-six years of elevated deer density in the Heart's Content forest. Balgooyen and Waller (1995) studied historic and recent deer effects on woody and herbaceous plant frequency and cover as well as overall plant species diversity in northern Wisconsin and its surrounding islands. All of these studies have resulted in management recommendations for their particular areas. These include the use of indicator species to gauge browsing impacts on vegetation as a whole, the construction of deer exclosures, reduction of the deer herd to appropriate levels, and the removal of undesirable browse-tolerant plant species that have become dominant. Since population trends for white-tailed deer in Ohio are similar to other areas of the eastern US (Shafer-Nolan 1997), these studies are useful as a general guide for deer management. However, because habitat, browse species, and management concern vary among regions, local studies are necessary to solve specific vegetation management issues related to deer browsing (Strole and Anderson 1992; Balgooyen and Waller 1995; Augustine and Jordan 1998).

We studied the regeneration of woodland vegetation following intense deer browsing in Sharon Woods, a central Ohio metropolitan park (Franklin County). This site was of interest because it typifies a suburban park, consisting of forested land bordered sharply by development (major highways on two of its four sides, and commercial/residential streets on the other two). The primary outcome of this study was the assessment of long term intense browsing (>10 yrs). This included measuring its effects on species diversity and determining whether browsing has favored certain plant species, thereby altering plant community composition. The deer population has recently been lowered at Sharon Woods, thus a secondary goal was to determine whether further

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reductions in deer density are necessary.

## MATERIALS AND METHODS

### Study Site

Sharon Woods Metro Park is one of 14 parks in central Ohio that make up the Columbus and Franklin County Metropolitan Park District. The 308 ha tract consists of woodland occupying 55.2% of the site, fields (17.3%), developed areas (13.4%), young successional areas (6.7%), wetland including ponds and woodland streams (4.5%), and plantings (4.3%) (Columbus and Franklin County Metropolitan Park District 2002). The wooded portion of the park is secondary growth beech-maple forest. Through the 1980s and early 1990s, the deer population at Sharon Woods rose due to growing urbanization around the park (Peck and Stahl 1997). In the mid-1980s, a decline in abundance of certain species within the plant families Liliaceae and Orchidaceae was first noticed, followed by a more general decline in spring wildflowers (J. Stahl, personal communication). By the late 1980s, more than 150 species of vascular plants were no longer found, and invertebrate, reptile, bird, and small mammal populations were reduced (Peck and Stahl 1997). Meanwhile, the deer herd peaked at 347 individuals (112 deer/km$^2$) in 1992, at which time deer management was implemented, consisting of culling and hormonal birth control. By 1997 these measures had reduced the population to the currently maintained level of ~40 individuals (~14 deer/km$^2$).

### Experimental Design

Park managers erected three deer exclosures in 1990, situated in representative habitats of Sharon Woods to evaluate vegetation regeneration after the deer population was reduced. The chosen habitats were a mesic forest upland site (Spring Hollow), a hydric forest (Swamp), and a forested area near a park trail with an intermediate soil moisture regime (Bike Trail). The exclosures were wire-fenced, 2.4 m in height, each enclosing approximately 0.4 ha. In spring 2002, sampling plots were established inside (fenced treatment) and immediately outside (browsed treatment) the 3 exclosures. Plot placement was accomplished using stratified random sampling design, wherein each exclosure plus an equal-sized adjacent browsed area was divided in half and a 0.1 ha plot placed at random in each half. Five, 4.0 m$^2$ vegetation cover sampling plots were randomly located within each 0.1 ha plot, giving a total of ten 4.0 m$^2$ plots per treatment per habitat. To avoid edge effects, a 2.0 m buffer zone flanking the perimeter of the enclosures was eliminated from sampling.

### Vegetation Analyses

Forbs, tree seedlings, lianas, and shrubs (collectively referred to as forest floor species) were identified and their abundance quantified at each site in early spring (late April – early May), late spring (late May – early June), and early summer (late June – early July) 2002. Trees and saplings were identified and measured in mid-summer. Within the 4.0 m$^2$ quadrats, all forest floor species were identified, their number of stems recorded, and visually assayed for percent cover using the Daubenmire (1959) class system with the following cutoff points: 0, 5%, 25%, 50%, 75%, and 95%. Within the 0.1 ha plots, woody saplings and trees were identified, measured, and counted, and any forest floor plants that were not captured in the 4.0-m$^2$ plots were recorded.

### Data Analysis

Percent cover values by species from each sampling period were combined for each site by including only the value from the individual period having the highest total cover for each plot, thereby reflecting the realized potential of each plot for vegetation cover. Seasonal forest floor species data were similarly integrated by selecting stem count values from the sampling period when individuals were most abundant. Because woody species abundances were fairly uniform over the course of a growing season, they were sampled only once.

Several indices were used to measure forest floor species diversity. The number of species present ($S$) was used as the measurement of richness. The Berger-Parker index ($1/d$) was used to measure species evenness where $d$ is the relative abundance of the single most dominant species ($d = N_{max}/N_{total}$), where $N$ is the number of individuals. The Shannon-Weiner index ($H'$) was used to measure species diversity, computed as

$$-\sum p_i \ln p_i$$

where $p_i$ is the proportional abundance of the $i$th species. Floristic quality was assessed based on the coefficients of conservatism ($C$) that have been assigned to each native species in Ohio (Andreas and others 2004). Conservatism values range from 0-10 based on the tolerance of the subject species to disturbance, and its fidelity to a particular pre-settlement plant community type. They are used to compute the Floristic Quality Assessment Index ($FQAI$), a community-level appraisal of natural quality, wherein $FQAI = \sqrt{N}$, in which $\overline{C}$ is the average conservatism of the plant community and $N$ is the number of native species present. Non-native species are not assigned conservatism values and so are not included in the $FQAI$ calculation.

For each forest floor species, relative abundance for each species was calculated as the sum of the abundance values for the species divided by the grand total of cover values for all species. Relative frequency (%) was calculated similarly, as the number of quadrats in which a species was recorded, divided by the total number of such occurrences for all species. Relative abundance and frequency were summed to derive an importance value ($IV$) to assess quadrat-level treatment effects on species composition and distribution. Data were analyzed with a two-factor analysis of variance that tested for site by treatment interactions. Dependent variables are cover (calculated using Daubenmire cover class data transformed into midpoints of the ranges), groundcover species diversity, evenness, richness, and floristic quality analyzed for differences between browsed and fenced treatments at the 4.0 m$^2$ level. Woody species data and comparisons above the 4.0 m$^2$ level were not analyzed statistically. Plant nomenclature follows Cooperrider and others (2001).

## RESULTS

### Forest Floor Species

Across all sites, forest floor plant cover was 60% greater in fenced compared to browsed plots ($F = 11.2$, $P = 0.002$, Fig. 1). There was a highly significant site by treatment interaction, however, with no treatment effect observed at the Swamp site. At the upland Spring Hollow site, plant cover was three times greater in fenced compared to browsed plots, and there were intermediate treatment effects at the Bike Trail site. In contrast to the overall negative effects of browsing on plant cover, we found little statistical support for treatment effects on species diversity ($H'$), richness ($S$), evenness ($1/d$), or floristic quality ($FQAI$) at any of the sites (Table 1). Trends were toward greater species richness and floristic quality in the fenced treatments but higher diversity ($H'$) and evenness in the browsed treatments.

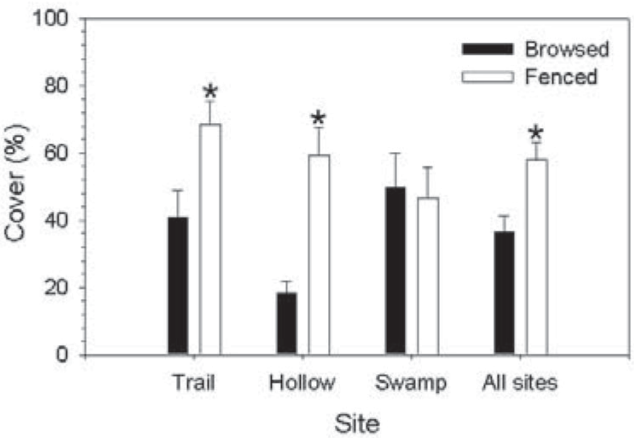


FIGURE 1. Forest floor plant cover in browsed and fenced areas of three habitats at Sharon Woods Metro Park. $n = 10$, bars indicate ± 1.0 SE.

TABLE 1

*Groundcover species diversity (H'), evenness (1/d), richness (S), and quality (FQAI) in browsed (B) and fenced (F) treatments at three sites at Sharon Woods. Mean ± (SE), n = 10. There were no statistically significant differences between treatments (ANOVA, P >0.05).*

| | Site | | | | | |
|---|---|---|---|---|---|---|
| | Trail | | Hollow | | Swamp | |
| Index | B | F | B | F | B | F |
| $H'$ | 1.19 (0.17) | 1.06 (0.12) | 1.45 (0.10) | 1.19 (0.16) | 1.06 (0.17) | 0.97 (0.15) |
| $1/d$ | 1.99 (0.34) | 1.65 (0.17) | 2.16 (0.15) | 1.89 (0.35) | 1.78 (0.17) | 1.56 (0.26) |
| $S$ | 8.40 (1.50) | 10.00 (0.91) | 8.90 (0.99) | 12.10 (1.66) | 7.50 (1.24) | 9.10 (1.95) |
| $FQAI$ | 6.74 (0.67) | 7.96 (0.94) | 10.62 (0.78) | 12.70 (1.10) | 7.73 (1.03) | 7.83 (1.36) |

Deer browsing had significant and dramatic effects on community composition as reflected by the relative frequencies and abundances of individual species. Seven of the 10 most frequently occurring plants were more often found in fenced plots. The frequency difference was statistically significant for two of these, jewel-weed (*Impatiens capensis*) and spicebush (*Lindera benzoin*) (Fig. 2). Among the 10 most abundant species based on stem counts, the following 4 were significantly more numerous in fenced compared to browsed plots: false mermaid (*Floerkia proserpinacoides*), poison ivy (*Toxicodendron radicans*), Japanese honeysuckle (*Lonicera japonica*), and wild ginger (*Asarum canadense*). Three additional species displayed trends in this direction that were not statistically significant (Fig. 3). For either frequency or abundance, only one statistically significant difference was found wherein browsed plots were favored over fenced plots: spring-beauty (*Claytonia virginica*) occurred only in browsed plots (Fig. 3).

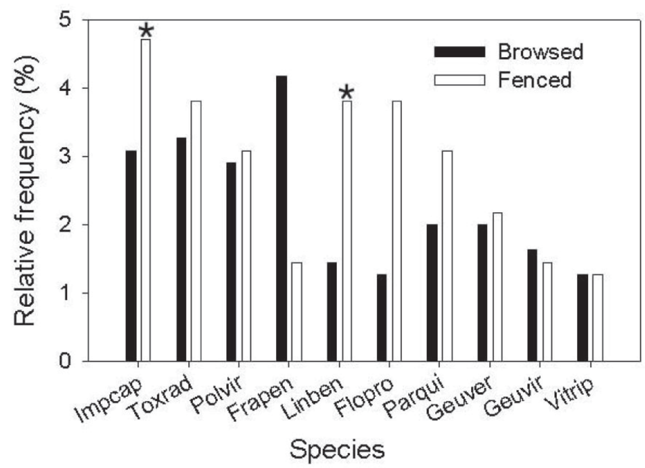


FIGURE 2. Relative frequencies of the 10 most frequent ground cover plants in browsed and fenced areas of Sharon Woods Metro Park ($N = 30$, 4.0 $m^2$ quadrats equally divided among the 3 sampling areas). Species (in decreasing order of frequency) are *Impatiens capensis*, *Toxicodendron radicans*, *Polygonum virginianum*, *Fraxinus pennsylvanica*, *Lindera benzoin*, *Floerkia proserpinacoides*, *Parthenocissus quinquefolia*, *Geum vernum*, *Geum virginianum*, and *Vitis riparia*. Asterisks indicate a significant treatment effect (Chi-square >3.84, $DF = 1.0$, $P < 0.05$).

Importance value (*IV*) is a summary statistic that combines relative frequency and relative abundance. Large differences in *IV* between treatments (≥2×) were observed for several of the most common species, such as false mermaid, poison ivy, yellow trout-lily (*Erythronium americanum*), red ash (*Fraxinus pennsylvanica*) and spicebush (Fig. 4). All except for red ash were of greater importance in fenced plots. Species more important in browsed treatments included cut-leaved toothwort (*Cardamine concatenata*, $IV = 16$), spring beauty ($IV = 11$) and pawpaw (*Asimina triloba*, $IV = 12$). All species of greater importance in browsed plots were native, ranging from low quality species like small-flowered agrimony (*Agrimonia parviflora*, $C = 2$) and spring-beauty ($C = 2$) to the higher quality species pawpaw ($C = 6$) and sugar maple (*Acer saccharum*, $C = 6$).

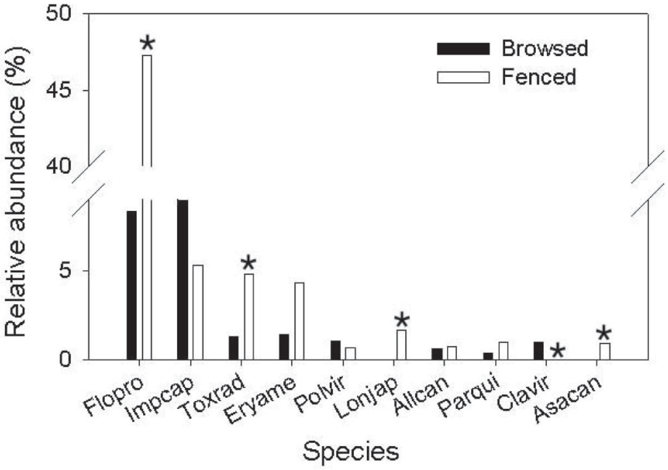


FIGURE 3. Relative abundances of the 10 most abundant forest floor species in browsed and fenced areas of Sharon Woods Metro Park ($n$ = 30, 4.0 m$^2$ quadrats equally divided among the 3 sampling areas). Species (in decreasing order of abundance) are *Floerkia proserpinacoides*, *Impatiens capensis*, *Toxicodendron radicans*, *Erythronium americanum*, *Polygonum virginianum*, *Lonicera japonica*, *Allium canadense*, *Parthenocissus quinquifolia*, *Claytonia virginiana*, and *Asarum candense*. Asterisks indicate a significant treatment effect ($t$-test, $P$ <0.05).

A substantial number of species were restricted to either browsed or fenced treatments (Table 2). Twenty-two species were found only in the fenced treatments, while 15 were restricted to the browsed treatments. The average coefficient of conservatism of treatment-specific species was significantly higher in the fenced plots than in the browsed plots ($t$ = 1.75, $P$ = 0.045). Six of the 21 species (29%) unique to the fenced treatment had notably high coefficients of conservatism ($C$ ≥6) and there was only one non-native species unique to the fenced treatments. The browsed treatments had only one unique high $C$ value species (8%) and three unique non-natives.

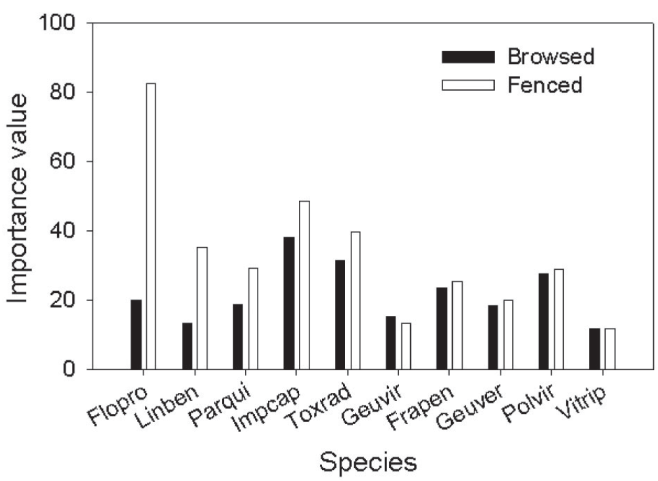


FIGURE 4. Importance values ($IV$ = relative frequency + relative abundance) of the 10 highest $IV$ ground cover plants in browsed and fenced areas of Sharon Woods Metro Park ($n$ = 30, 4.0 m$^2$ quadrats equally divided among the 3 sampling areas). Species (in decreasing order of difference between treatments) are *Floerkia proserpinacoides*, *Lindera benzoin*, *Parthenocissus quinquefolia*, *Impatiens capensis*, *Toxicodendron radicans*, *Geum virginianum*, *Fraxinus pennsylvanica*, *Geum vernum*, *Polygonum virginianum*, and *Vitis riparia*.

TABLE 2

*Species unique to browsed and fenced treatments at Sharon Woods Metro Park arranged in decreasing order of coefficient of conservatism (C).*

| Treatment-specific species | | | |
|---|---|---|---|
| Browsed | *C* | Fenced | *C* |
| *Aesculus glabra* | 6 | *Fraxinus nigra* | 7 |
| *Hamamelis virginiana* | 5 | *Orchis spectabilis* | 7 |
| *Sanguinaria canadensis* | 5 | *Asarum candense* | 6 |
| *Trillium sessile* | 5 | *Caltha palustris* | 6 |
| *Galium concinnum* | 5 | *Dicentra cucullaria* | 6 |
| *Dioscorea villosa* | 4 | *Lilium michiganense* | 6 |
| *Galium circaezans* | 4 | *Cornus florida* | 5 |
| *Senecio aureus* | 4 | *Euonymus obovatus* | 5 |
| *Agrimonia parviflora* | 2 | *Phryma leptostachya* | 5 |
| *Claytonia virginica* | 2 | *Polemonium caeruleum* | 5 |
| *Viburnum recognitum* | 2 | *Rosa palustris* | 5 |
| *Oxalis stricta* | 0 | *Solidago flexicaulis* | 5 |
| *Catalpa bignonioides* | † | *Trillium grandiflorum* | 5 |
| *Rhamnus cathartica* | † | *Phlox divaricata* | 4 |
| *Viburnum opulus* | † | *Podophyllum peltatum* | 4 |
| | | *Smilacina racemosa* | 4 |
| | | *Ribes cynosbati* | 3 |
| | | *Sambucus canadensis* | 3 |
| | | *Sanicula trifoliata* | 3 |
| | | *Celastrus scandens* | 2 |
| | | *Erigeron philadelphicus* | 2 |
| | | *Lonicera tatarica* | † |
| Mean C | 3.67 | | 4.67 |

† introduced species

## Tree Recruitment

Most canopy tree species in Sharon Woods have continued seedling recruitment, with the overall tree population exhibiting a reverse J-shaped size distribution (Fig. 5). At the Spring Hollow site, seedlings and saplings smaller than 10.0 cm dbh were more plentiful in the browsed treatment than the fenced treatment, but at the Bike Trail site the reverse was true. At the Swamp site, there was no apparent effect of browsing on any size class. These contrasting results were due to the differential success of individual tree species under browsing pressure, some of which were absent from one or two of the sites (Asnani 2003). Overall, sugar maple, pawpaw, American beech (*Fagus grandifolia*), ironwood (*Carpinus caroliniana*) and hop-hornbeam (*Ostrya virginiana*) all increased in abundance in the browsed treatment (Fig. 6). Conversely, bitternut hickory (*Carya cordiformis*) and red ash were more successful in the fenced treatment. American elm (*Ulmus americana*) and slippery elm (*Ulmus rubra*) recruited equally well under browsing pressure as under protection, while red maple (*Acer rubrum*) and pin oak (*Quercus palustris*) did not appear to be recruiting at all.

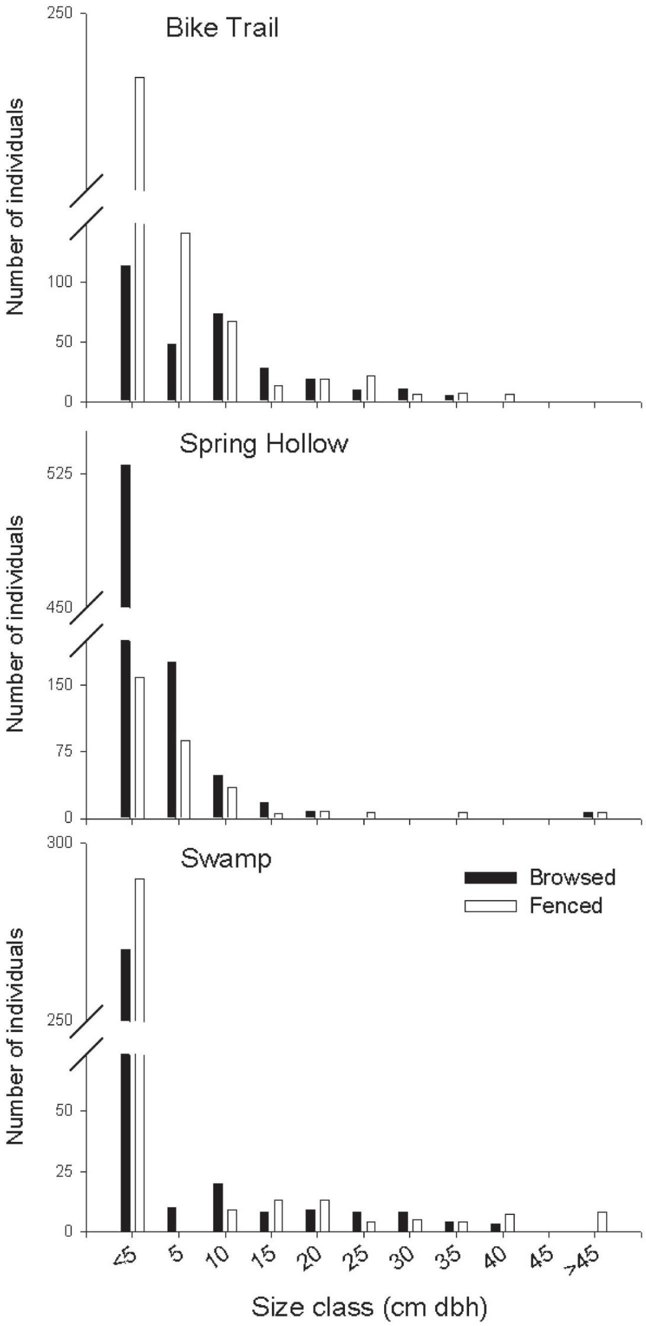


FIGURE 5. Frequency of trees in different size classes at the Bike Trail, Spring Hollow, and Swamp sites within browsed and fenced treatments.

## DISCUSSION

Forest floor plant cover had not fully recovered under reduced browsing pressure in at least two of the three habitats we sampled at Sharon Woods. At all of the sites, understory vegetation had the potential for at least 75-95% cover, but at the Bike Trail and Spring Hollow sites the largest proportion of browsed plots had only 5-25% cover. At Spring Hollow, vegetation in the browsed plots was the sparsest, with 70% of browsed plots being in the 5-25% cover category. Spring Hollow supports the most species in the Liliaceae and Orchidaceae, families known to be especially susceptible to browsing (Miller and others 1992).

We saw consistent trends toward greater richness (*S*) and floristic quality (*FQAI*) in fenced treatments, an indication that some of the more sensitive species capable of regenerating under complete protection had not yet recovered under the reduced browsing pressure of the current deer management regimen. While both higher ($C \geq 6$) and lower quality species, including several non-natives, have been favored in fenced treatments, deer browsing more severely limits the regeneration of higher quality species at Sharon Woods. There were some notable exceptions, however. Sugar maple and pawpaw are both conservative woody species ($C = 6$) that were more frequent in browsed compared to fenced plots. Other researchers have observed sugar maple to be non-preferred by deer (Strole and Anderson 1992; Anderson and Katz 1993) while horticulturalists recommend pawpaw for use in areas where deer damage is a concern (Fargione and others 1991). Surprisingly, consistent trends toward reduced species diversity (*H'*) and evenness (*1/d*) were noted in the fenced treatments. This was evidently caused by the numerical, as opposed to spatial, abundance of the mat-forming diminutive spring ephemeral false mermaid.

Browsing-induced differences in species composition also were reflected in the unique species occurring in both treatments, most of which were not abundant enough to be represented in frequency or abundance data. Unique fenced treatment species, such as Michigan lily (*Lilium michiganense*), showy orchis (*Orchis spectabilis*), and may-apple (*Podophyllum peltatum*) had a higher mean *C* than did unique browsed treatment species, which also included more non-natives. These conservative species may increase in overall abundance at Sharon Woods, given additional time to recover from browsing pressure. Augustine and Frelich (1998) demonstrated the potential for a re-introduced sensitive species to exist at low deer density in their study on *Trillium* spp. in Minnesota. Transplant

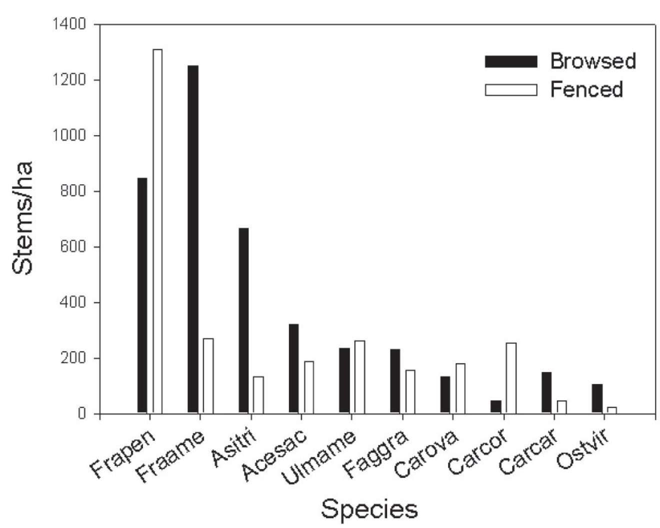


FIGURE 6. Abundance of juvenile trees (≤10cm dbh) in browsed and fenced areas of Sharon Wood Metro Park. Species (in decreasing order of abundance) are *Fraxinus pennsylvanica*, *Fraxinus americana*, *Asimina triloba*, *Acer saccharum*, *Ulmus americana*, *Fagus grandifolia*, *Carya ovata*, *Carya cordiformis*, *Carpinus caroliniana*, and *Ostrya virginiana*.

experiments revealed that there was no significant difference in proportion of transplants retaining leaves between protected and unprotected plants at low deer density (4 deer/km$^2$). It is therefore possible that recovery can occur in unprotected areas of Sharon Woods at an appropriate deer density.

While woody species as a whole did not appear to be declining at Sharon Woods, subtle shifts in composition may be occurring, evidenced by reduced abundance of oaks and greater abundance of American beech, sugar maple, and pawpaw in browsed compared to fenced treatments. With the exception of red maple and pin oak, all tree species present in sufficient numbers showed a reverse J-shaped distribution, indicating that new trees were being recruited. Species categorized as slow-growing, shade tolerant, and long lived (Tilghman 1989; Waller and Alverson 1997; Sutherland and others 2000), that is, sugar maple, ironwood, American beech, hop-hornbeam, and pawpaw, generally recruited more in browsed than in fenced treatments. It is probable that shade tolerance and unpalatability contribute to the success of these species under disturbed conditions and they could interfere with regeneration of more sensitive, less shade tolerant oaks (Anderson and Katz 1993; DeCalesta 1994; Waller and Alverson 1997). In Illinois, heavy shading from both sugar maple and pawpaw inhibited regeneration of white oak (*Quercus alba*) (Shotola and others 1992) and strong competition from pawpaw restricted the regeneration of other canopy species as well (Robertson and others 1978).

It is likely that substantial species recovery has taken place in Sharon Woods, as species diversity was not significantly reduced, and nearly all major woody species were recruiting. However, vegetation cover in general was significantly lower in some browsed areas and there was a consistent trend toward reduced species richness and floristic quality in browsed treatments in all three habitats. Shifts in species composition have occurred toward more disturbance and shade-tolerant species that may inhibit regeneration of more palatable, sensitive species. Both those successful but less desirable species, and the more sensitive species, such as white trillium (*Trillium grandiflorum*) and showy orchis, should be monitored for long-term changes in abundance. Reintroduction should be considered for species that are slow to become established on their own.

Though the appropriate deer density for Sharon Woods cannot be directly predicted by this study, inferences can be made from the condition of the vegetation. In this study, herbaceous species and woody species seemed to be limited by different factors. Greater sapling and tree seedling abundance in browsed treatments indicates that the regeneration of many tree species is not being limited by herbivory, but may be limited by competition inside fenced treatments, since there was significantly greater cover of forest floor species inside exclosures. This greater vegetation cover under protection from browsing also suggests that forest floor species are limited by herbivory. Herbs and woody vegetation have different levels of tolerance for browsing where herbaceous species are most sensitive to overbrowsing because they cannot outgrow herbivores (Alverson and others 1988).

Ecosystem-level tolerance to herbivory is quantified by the concept of relative deer density (*RDD*). DeCalesta and Stout (1997) defined *RDD* as a proportion of carrying capacity (*K*) where the *RDD* appropriate for sustained timber productivity (*RDDt*) is 20-39% of *K*, whereas the *RDD* appropriate for sustained biodiversity (*RDDs*), which includes all plant species, is less than 20% of *K*. Since the majority of tree species in Sharon Woods are successfully recruiting, it can be inferred that deer density did not greatly exceed *RDDt*, but it almost certainly does not meet *RDDs*. For forests lacking additional forage provided by agricultural fields, *K* was estimated at 25 deer/km$^2$ (DeCalesta and Stout 1997), which corresponds well to findings from studies in northern Wisconsin and northeastern Illinois (Alverson and others 1988; Anderson 1994; Balgooyen and Waller 1995) where 4-6 deer/km$^2$ were recommended. Deer density estimates fluctuate at Sharon Woods, but 10-20 deer/km$^2$ was the last estimate we obtained (A. Shaw, *personal communication*). The condition of herbaceous vegetation indicates this is not an appropriate density for full recovery of biodiversity, though further monitoring of this vegetation type is essential to gauge its recovery. We conclude that as a first step to restoring biodiversity at Sharon Woods, consideration should be given to further reducing deer density to 4-6 deer/km$^2$.

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